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An Overview on Drying

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ABSTRACT

This paper describes the various methods of drying technologies that are used in the pharmaceutical industry. Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semisolid, or liquid. Various equipment used for drying includes tray dryer, vacuum dryer, spray dryer, etc. Various methods involved in the drying process were the mechanical method, electrical method, and natural convection method. This review paper discusses in detail the principle and working of tray dryer, vacuum dryer, spray dryer, fluidized bed dryer, and drum dryer. And also discusses the advantages, disadvantages, and uses of various equipment used in drying. The equipment normally used for the purpose of proper drying and their related details are discussed in this review paper with the deep knowledge of dryers and drying mechanisms, an efficient drying process in the pharmaceutical industry can be achieved.

INTRODUCTION

Drying is defined as the removal of a small amount of water or other liquid from a material by the application of heat or the final removal of liquid from solids by vaporization with the aid of heat[1]. The equipment used for drying is called a dryer. The main purpose of drying is to avoid or eliminate moisture which may lead to corrosion and decrease the product or drug stability, to improve or keep the good properties of a material examples flowability, compressibility, to reduce the cost of transportation of large volume materials, to make the material easy or more suitable for handling. Drying and evaporation are relatively the same terms but are distinguished in terms of the removal of water.

ADVANTAGES OF DRYING

- Easy handling.
- Reduced labor cost.
- High thermal efficiency.
- Facilitate grinding of the crude drug.
- For easy transport and storage.
- Helps to reduce bulk density and weight[2].

DISADVANTAGES OF DRYING

- More expensive.
- Develop electric charge[3].
- There is a risk of fire and explosion, so care must be taken to avoid flammability limits in the dryer.

APPLICATIONS OF DRYING

- Used in manufacturing of granules.
- Used to reduce the bulk and weight of the material.
- It helps in the preservation of crude drugs or plants from mold growth.

- It helps in the size reduction process[4].

- Preservation of drug products: Drying is necessary in order to avoid deterioration. A Few examples are Crude drugs of animal and vegetable origin, blood products, and skin tissues.

- Preparation of bulk drug: In the preparation of the bulk drug, drying is the final stage of processing. The drying step is essential after a certain operation such as crystallization and filtration. Eg: Dried aluminum hydroxide.

- Improved handling: Removal of moisture makes the material light in weight and reduces the bulkiness. Thus, the cost of transportation will be less and storage will be efficient. If moisture is a present size reduction of drugs is difficult. Drying reduces the moisture content.

- Improved characteristics like shape, and uniform size. Drying yields materials of spherical shape, uniform size free-flowing, and enhanced solubility.

- Purification of crystalline products.

- Drying shows the importance in a specific area like drying of granules are to improve fluidity and compression characteristics. These are essential for the production of tablets and capsules examples include male fern extract, malted extract, and oleoresin.

THEORY OF DRYING

In a wet solid mass, water may be present as bound water and unbound water. Bound water (moisture) is the minimum water (moisture) held by the material that exerts an equilibrium vapor pressure less than the pure water at the same temperature[5]. Unbound water (moisture) is the amount of water (moisture) held by the material that exerts an equilibrium vapor pressure equal to that of pure water at the same temperature[6]. Difference between bound and unbound water is shown in figure 1.

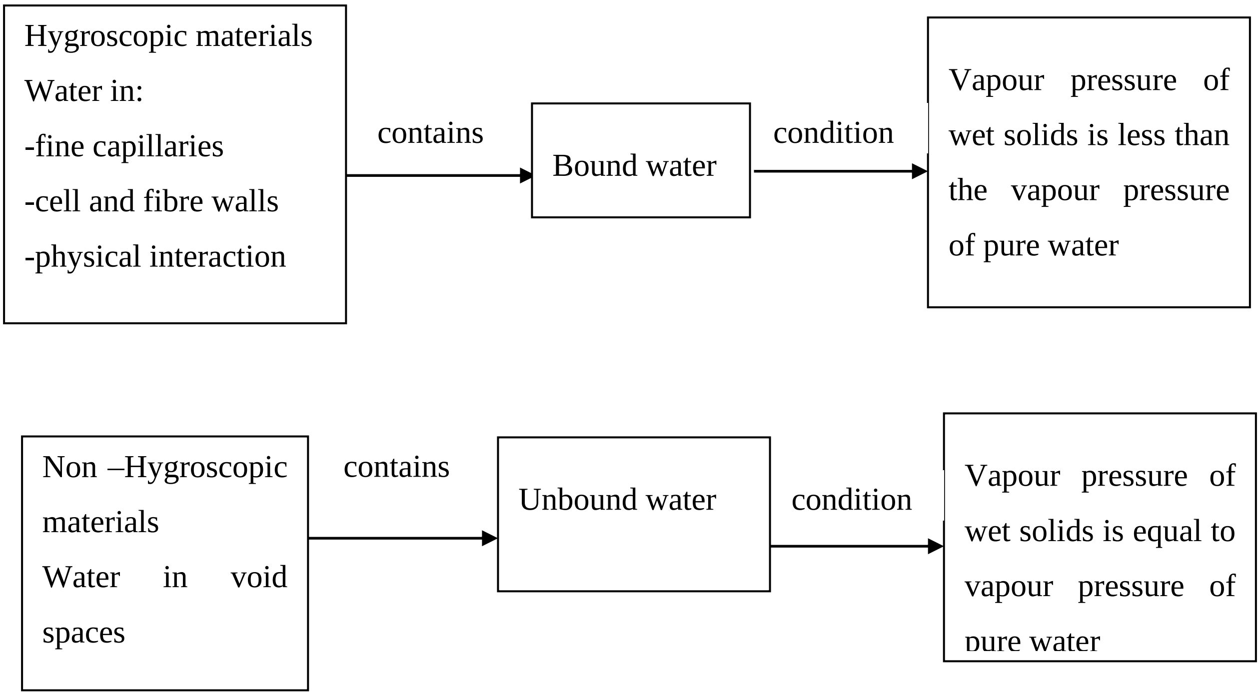

Fig.No. 1: Difference of bound and unbound water

MECHANISMS OF DRYING PROCESS

Drying involves both heat transfer and mass transfer processes simultaneously.

-Heat transfer takes place from the heating medium to the solid material.

-Mass transfer involves the transfer of moisture to the surface of the solids and subsequently vapourization from the surface into the surroundings.

Various theories are that explain the movement of moisture are diffusion theory, capillarity theory, and pressure gradient theory[7].

Diffusion theory: Diffusion theory assumes that the effect of capillarity gravitational and friction forces are too small. In diffusion theory, the rate of flow of water is proportional to the moisture gradient.

Capillarity theory: Capillarity theory is applicable to porous granular solids. Porous material contains a network of interconnected pores and channels, which are not circular or straight.

Pressure gradient theory: Pressure gradient theory is applicable to the drying of solids by application of radiation (not external heating).

The theory of drying can be discussed under two headings mainly equilibrium relationship and rate relationship. Equilibrium relationship air of constant humidity and temperature is passed over wet material after long exposure equilibrium is reached. Equilibrium moisture content (EMC) is the amount of water that exerts vapor pressure on the atmosphere surrounding it. Based on the conditions of humidity and temperature solid will either lose or absorb the moisture. When air is continuously passed over the solid containing moisture more than EMC then the solid loses water till the EMC is reached. This phenomenon is known as desorption. When air is continuously passed over the solid containing moisture less than EMC then solid absorb water till the EMC is reached. This phenomenon is known as sorption. Free moisture content (FMC) is the amount of water that is free to evaporate from a solid.

$$\text{FMC} = \text{Total water content} - \text{EMC}$$

Rate relationship is observed by considering a simple model which mimics the conditions of a dryer. In this model wet slab of solid is considered and hot humid air is passed over it. The change in weight is determined by weighing the slab at a different time interval and the following calculation is made.

$$\%\ \text{loss on drying (LOD)} = \frac{\text{mass of water in a sample (kg)}}{\text{The total mass of the wet sample(kg)}} \times 100$$

$$\%\ \text{moisture content (MC)} = \frac{\text{mass of water in sample (kg)}}{\text{The total mass of the dry sample(kg)}} \times 100$$

$$\text{Drying rate} = \frac{\text{weight of water in sample (kg)}}{\text{Time(h)} \times \text{weight of the dry solid (kg)}}$$

Factors affecting drying

- Particle size
- Nature of material
- Nature of moisture
- Surface area

- Initial and final moisture content
- Thickness and material bed
- Temperature
- Amount of moisture
- Nature of the product[8]

CLASSIFICATION OF DRYING EQUIPMENT

The classification based on the method of solids handling is more suitable when special attention is given to the nature of the material to be dried.

TRAY DRYER

Fig. No. 2: Tray dryer

In-tray dryer, hot air is continuously circulated. Forced convection heating takes place to remove moisture from the solids placed in trays. Simultaneously most air is removed partially[9].

It consists of a rectangular chamber whose walls are insulated. Trays are placed inside the heating chamber. The number of trays may vary with the size of the dryer. Dryers of laboratory size may contain a minimum of 3 trays, whereas dryers of industry size may contain more than 20trays. Each tray is rectangular or square and about 1.2 to 2.4meters square in area. Trays are usually loaded from 10.0 to 100.0 mm deep. The distance between the bottom of the upper tray and the surface of the substance loaded in the subsequent tray must be 40.0mm.

Wet solid is loaded into trays. Trays are placed in the chamber. Fresh air is introduced through the inlet, which passes through the heater and gets heated up. The hot air is circulated by means of fans at 2 to 5 meters per second. Turbulent flow lowers the partial vapor pressure in the atmosphere and also reduces the thickness of the air boundary layer. The water is picked up by air. As water evaporates from the surface, the water diffuses from the interior of the solid by capillary action. These events occur in a single pass of air. The time of contact is short and the amount of water picked up in a single pass is small. Therefore, the discharged air to the tune of 80 to 90% is circulated back through fans. Only 10 to 20% of fresh air is introduced. Moist air discharged through the outlet. Thus, constant temperature and uniform airflow over the material can be maintained for achieving uniform drying. In the case of wet granules, drying is continued until the desired moisture content is obtained. At the end of the drying, trays are pulled out of the chamber and taken to a tray dumping station. A schematic diagram of the tray dryer is shown in figure 2.

Sticky material[10], granular mass, or crystalline material can be dried in a tray dryer. In-tray dryer mainly involving advantages are handling of materials can be done without losses, the same equipment is readily adjusted with the chemical industry. Thedemerits of tray dryer requires more labor to load and unload hence cost increases, and also the process is time-consuming.

DRUM DRYER

In drum dryer heated shallow metal drum rotates on its longitudinal axis, which is partially dipped in the solution to be dried. The solution is carried as a film on the surface of the dryer and dried to form a layer[11].

A suitable knife scraps the dried material, while the drum is rotating. Its consists of a horizontally mounted hollow steel drum of 0.6 to 3.0 meters diameter and 0.6 to 4.0 meters length, whose external surface is smoothly polished. Below the drum, the feed pan is placed in such a way that the drum dips partially into the feed. On one side of the drum, a spreader is placed and on the other side, a doctor’s knife is placed to scrap the dried material. A storage bin is placed connecting the knife to collect the material. Steam is passed inside the drum. The heat transfer coefficient of the drum metal is high.

Drying capacity is directly proportional to the surface area of the drum. Heat is transferred by conduction to the material[12]. Simultaneously drum is rotated at a rate of 1-10 rpm. The liquid material present in the feed pan adheres as a thin layer to the external surface of the drum during its rotation. The material is completely dried during its journey in slightly less than one rotation. The schematic diagram of the drum dryer is shown in figure3. The dried material is scraped by the doctor's knife which then falls into a storage bin. Therefore, processing condition such as film thickness, the steam temperature is closely controlled. Drum dryer is used for drying solution, slurries, suspension[13,] etc. The products dried are milk products, starch products, ferrous salts, suspension of zinc oxide, etc.

The merits of drum dryer, drying time are less, only a few seconds. Therefore heat-sensitive materials can be dried. Drum dryer occupies less space as it is compact when compared to the spray dryer. The demerits of drum dryer are maintenance cost is higher than spray dryer, skilled operators are essential to control feed rate, film thickness, speed of rotation, and temperature.

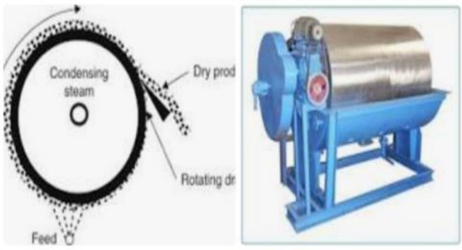

Fig. No. 3: Drum dryer

SPRAY DRYER

The fluid to be dried is atomized into fine droplets, which are thrown radially into moving steam of hot gas[14]. The temperature of the droplets is immediately increased and fine droplets get dried instantaneously in the form of spherical particles. This process completes in a few seconds before the droplets reach the wall of the dryer.

It consists of a large cylindrical drying chamber with a short conical bottom, made up of stainless steel. An inlet for hot air is placed on the roof of the chamber. Another inlet carrying spray disk atomizer is set on the roof. The spray disk atomizer is about 300 millimeters in diameter and rotates at a speed of 3000 to 50000 revolutions per minute. The bottom of the dryer is connected to a cyclone separator. Drying of the material in the spray dryer involves 3 stages[15].

- Atomization of the liquid

- Drying of the liquid droplets
- Recovery of the dried product

Atomization of the liquid

The feed is introduced through the atomizer either by gravity or by using suitable plumb to form fine droplets. The properties of the final product depend on the droplet form, hence the selection of the type of atomizer is important. The atomizer of any type of pneumatic atomizer, pressure nozzle, and spinning disc atomizer may be used. The rate of feed is adjusted in such a way that the droplets should be completely dried before reaching the walls of the drying chamber. At the same time, the product should not be overheated.

Drying of the liquid droplets

Fine droplets are dried in the drying chamber by supplying hot air through the inlet. The surface of the liquid drop is dried immediately to form a tough shell. Further, the liquid inside must escape by diffusing through the shell at a particular rate. At the same time, heat transfer from outside to inside takes place at a rate greater than the liquid diffusion rate. As a result, the heat inside mounts up which allows the liquid to evaporate at a faster rate. This tendency of a liquid leads to a rise in internal pressure, which causes the droplets to swell. The shell's thickness decreases whereas permeability for vapor increases. If the shell is neither elastic nor permeable, it ruptures and the internal pressure escapes. The temperature of the air is adjusted in such a way that the droplets should be completely dried before reaching the walls of the drying chamber. At the same time, the product should not be overheated.

Recovery of the dried product

The centrifugal force of the atomizer drives the droplets to follow a helical path. Particles are dried during their journey and finally fall at the conical bottom. All these processes are completed in a few seconds. The particle size of the final product ranges from 2 to 500mm. Particle size depends on solid content in the feed, liquid viscosity, feed rate, and disc speed. Spray dryers of maximum size have got evaporating capacity of up to 2000kg per hour. The uses of spray dryer are the product is a better form than that obtained by any other dryer, the quantity of the material to be dried is large, the product is thermolabile, hygroscopic, or undergoes chemical decomposition. The main advantages are spray drying is a continuous process and drying is very rapid. Drying completes within 3 to 30sec labor costs are low as it combines the function of an evaporator, a crystallizer dryer a size reduction unit, and a classifier, it is suitable for the drying of the sterile product. Demerits of spray dryers are very bulky and expensive. Such huge equipment is not always easy to operate. The thermal efficiency is low, as much heat is lost in the discharged gases. The schematic diagram of the spray dryer is shown in figure 4.

Fig. No. 4: Spray dryer

FLUIDIZED BED DRYER

The schematic diagram of the fluidized bed dryer is shown in figure5. Hot air is passed at high pressure through a perforated bottom of the container containing granules to be dried[10]. The granules are lifted from the bottom and suspended in the stream of air. This condition is called fluidized state[16].

The hot gas is surrounding every granule to completely dry them. Thus, materials or granules are uniformly dried. Two types of bed dryers are available, vertical fluid bed dryer and horizontal fluid bed dryer. The dryer is made up of stainless steel or plastic.

A detachable bowl is placed at the bottom of the dryer, which is used for charging and discharging[17]. The bowl has a perforated bottom with a wire mesh support for placing materials to be dried. A fan is mounted in the upper part for circulating hot air. Fresh air inlet, prefilled and heat exchanger are connected serially to heat the air to the required temperatures. The temperature of hot air is monitored. Bag filters are placed above the drying bowl for the recovery of fines.

The wet granules to be dried are placed in the detached bowl. The bowl is pushed into the dryer. Fresh air is allowed to pass through a prefilled, which subsequently gets heated by passing through a heat exchanger. The hot air flows through the bottom of the bowl. Simultaneously fan is allowed to rotate. The air velocity is gradually increased.

When the velocity of the air is greater than the settling velocity of granules, the granules remain partially suspended in the gas stream. After some time, a point of pressure is reached at which frictional drag on the particles is equal to the force of gravity. The granules rise in the later fall back in a random boiling motion. This condition is said to be a fluidized state. The gas surrounds every granule to completely dry them. The air leaves the dryer by passing through the bag filter. The engrained particles remain adhered to the inside surface of the bags. Periodically the bags are shaken to remove the entrained particles. Intense mixing between granules and hot gas provides uniform conditions of temperature composition and particle size distribution. Drying is achieved at a constant rate and the falling rate period is very short. Any attempt to increase the air velocity may result in entrainment. The residence time for drying is about 40minutes. The material is left for some time in the dryer for reaching ambient temperature. The bowl is taken out for discharging. The end product is free-flowing.

A fluidized bed dryer is popularly used for drying granules in the production of tablets. A fluidized bed layer can be used for three operations such as mixing, granulation, and drying. It is modified for the coating of granules.

The advantages of a fluidized bed dryer require less time to complete drying, handling time is also short. It is 15 times faster than the tray dryer. It is available in different sizes with a drying capacity ranging from 5 to 200 kg per hour. Thermal efficiency is 2 to 6 times that tray dryer. The demerits of fluidized bed dryer many organic powders develop electrostatic charges during drying. To avoid this efficient earthling of the dryer is essential. The turbulence of the fluidized state of granules may cause attrition of some material resulting in the production of fines but using a suitable binding agent this problem can be solved. Fine particles may become engrained and must be collected by bag filters.

Fig. No. 5: Fluidized bed dryer

VACUUM DRYER

The material is dried by the application of a vacuum. When the vacuum is created; the pressure is lowered so that water boils at a lower temperature[18]. Hence water evaporates faster. The heat transfer becomes efficient; the rate of drying enhances substantially.

It is made of a cast-iron heavy jacketed vessel. It is so strong that it can withstand a high vacuum within the oven and steam pressure in the jacket. The schematic diagram of the vacuum dryer is shown in figure 6. The enclosed space is divided into a number of portions by means of 20 hollow shelves, which are part of the jacket. These shelves provide a larger surface area for conduction of here. Over the shelves, metal trays are placed for keeping the material. The oven door can be locked tightly to give an air-tight seal. The oven is connected to a vacuum pump by placing a condenser in between.

The material to be dried is spread on trays. The trays are placed on the shelves and the door is closed firmly. Pressure decreases up to 30 to 60-kilo pascals by means of a vacuum pump. Steam or hot air is supplied into the hollow space of the jacket and shelves transfer by conduction takes place[19]. In this vacuum, evaporation of water from the material takes place at 25-30˚C, on account of lowering of boiling point. Water vapor passes into the condenser where condensation takes place. At the end of the drying vacuum line is disconnected. The material is collected from the trays.

The vacuum dryer is used for heat-sensitive materials, which undergo decomposition. Dusty and hygroscopic materials, drugs containing toxic solvent. These can be separated into closed containers, feed containing valuable solvents. These are recovered by condensation. Advantages of the vacuum dryer are providing a large surface area for heat transfer, handling of material, tray and equipment is easy, It is easy for switching over to the next materials. The demerits included low transfer coefficient, limited capacity and use for a batch process, more expensive than tray dryer, and labor and running costs are also high. The schematic diagram of the vacuum dryer is shown in figure 6.

Fig. No. 6: Vacuum dryer

FREEZE DRYER

Freeze dryer which is also known as lyophilizer is a system that is made solvent loving for removing the same[20].In freeze-drying, water is removed from the frozen state by sublimation i.e direct change of water from solid into vapor without conversion to a liquid phase. Solid – liquid-vapor equilibrium phase diagram of water is useful to decide the experimental conditions. The drying is achieved by subjecting the material to temperature and pressure below the triple point. Under these conditions, any heat transferred is used as latent heat, and ice sublime directly into the vapor state. The water vapor is removed from the system by condensation in a cold trap maintained at a temperature lower than the frozen material.

It consists of a drying chamber in which trays are located, heat supply in the form of the radiation source, heating coils, vapor condensing or adsorption system vacuum pump or steam ejector, or both. The chamber for vacuum dryers is generally designed for batch operation[21].

It consists of shelves for keeping the material. The distances between subliming surface and condenser must be less than the mean path of molecules. This increases the rate of drying. The condenser consists of a relatively large surface cooled by solid carbon dioxide slurred with acetone or ethanol. The temperature of the condenser must be much lower than the evaporated surface of the frozen substance. In order to maintain this condition, the condenser surface is cleaned repeatedly.

A freeze dryer is most commonly used in the production of dosage forms such as injections, solutions, and suspension[22]. It is used for drying a number of products, blood plasma and its fractional products, bacterial and viral culture, human tissue antibiotics, and plant extracts. Advantages of freeze dryer include drying of thermolabile materials, maintenance of stability, and no denaturation. Demerits of freeze dryer equipment and running costs are high and it is difficult to afoot the method for a solution containing nonaqueous solvents. The schematic diagram of the freeze dryer is shown in figure 7.

Fig. No.7: Freeze dryer

DISCUSSION

Drying is the removal of a small amount of water or other liquid from a material by the application of heat. The equipment used for drying is called a dryer. The main advantages of drying are easy handing, reduced labor cost, high thermal efficiency, and reduced bulk density and weight. And the demerit of drying is more expensive, develop electric charge and there is a risk of fire and explosion, so care must be taken to avoid flammability limits in the dryer. Here the equipment involved spray dryer, vacuum dryer, tray dryer, etc. The tray dryer is mainly used for the sticky material, granular mass or crystalline material can be dried in a tray dryer. Drum dryer is used for drying solution, suspension, etc. And the as compared tray dryer to vacuum dryer it is more expensive than tray dryer and labor and running costs are also high. A spray dryer is suitable for the drying of sterile products. But the spray dryer is very bulky and expensive. A fluidized bed layer can be used for three operations such as mixing, granulation, and drying. A freeze dryer is most commonly used for drying.

CONCLUSION

Drying is the removal of a small amount of water or other liquid from a material by the application of heat. The equipment used for drying is called a dryer. The equipment includes a spray dryer, drum dryer, vacuum dryer, etc. Dryer used for drying solutions, suspension, and also dryers are used in a variety of industries, such as the food processing, pharmaceutical, paper, pollution control, and agricultural sectors. In the pharmaceutical industry, drying technology is unavailable to avoid or eliminate moisture which may lead to corrosion and decrease the product or drug stability and to improve or keep the good properties of a material,e.g. flowability, compressibility. In conclusion, the drying process is not complicated but it needs several different simulations to get the optimistic temperature for avoiding any waste of energy and time.

REFERENCES

1. Sherwood K; The drying of solids-1.Industrial and engineering chemistry 1929; 21(1): 12-16.
2. Martin F; Current approaches of preservation of cell during drug. Journal of pharmaceutical sciences 2021; 110(8): 2873-2893.
3. Sadjad A; Drying technology. An international journal performance of a recirculating dryer equipped with a desiccant wheel 2015; 34(5): 863-870.
4. Shahram N, Paul R; Emerging bio drying technology for the drying of pulp and paper mixed sludges. Taylor and francis online 2006; 24(7): 863-878.
5. Jeffry S, Lacey E; Partial removal of pure and loosely bound water by low energy drying decreases cortical bone toughness in young and old donors. Journals of the medical behavior of biomedical materials 2013; 22(4): 136-145.
6. Mujumbar A; Drying fundamentals. Industrial drying of foods 1997; 1(2): 7-30.
7. Johnner P, Istali A; Modelling and simulation of momentum, heat and mass transfer in a dryer. Taylor and francis online 2003; 21(2): 217-229.
8. Hong Y, Harianto R; Factors affecting drying and wetting solid-water characteristics curves of sundy soils. Canadian geotechnical journal 2004; 41(5): 908-920.
9. Bahubali N, Vamshi K; Equipment qualification of a new laboratory tray dryer. Research journal of pharmacy and technology 2019; 12(2): 805-811.
10. Suhaimi M; Review on the application of a tray dryer system for agricultural products. World applied science journal 2013; 22(3): 424-433.
11. Savita B, Revanth V; Development and scale-up of a chemical process in the pharmaceutical industry. International journal engineering research 2016; 6(7): 81-88.
12. Almena A, Serafim B; Optimising food dehydration process energy efficient drum operation. Energy procedia 2019; 161(1): 174-181.
13. Sefa T, Telci M; Product quality and energy consumption when drying peppermint by rotatory drum dryer. Industrial crops and products 2010; 32(3): 420-427.
14. Patel R, Suthar M; Spray drying technology: an overview. International journal of science and technology 2009; 2(10): 44-47.
15. Mahmoud A; Spray drying of biopharmaceuticals stability and process consideration. Taylor and francis online 2006; 24(6): 763-768.
16. Ravi T, Venkateswara R; Fluidized bed processing a review. Indian journal of research in pharmacy and biotechnology 2014; 2(4): 1360-1366

17. Wan R; Fluidized bed dryer recent advances. Advanced power technology 2008; 19(5): 403-418.
18. Dilip M; Vacuum drying basis and application. Chemical engineering 2015; 124(4): 48-54.
19. Dilip P; Vacuum dryer basis and application. Chemical engineering –NewYork 2015; 122(40): 48-56.
20. Xialin C, Steven L; Freeze drying process design by manometric temperature measurement design of a smart freeze dryer. Pharmaceutical research 2005; 22(4): 685-700.
21. Athanasios 1; Optimal control of a freeze dryer theoretical development and quasi-steady-state analysis. Chemical engineering science 1979; 34(7): 975-981.
22. Soham S; Freeze drying process a review. International journal of pharmaceutical science and research 2011; 2(12): 3061-3067.